141

SATURN GENERAL PROTUBERANCE FORCE ANDPRESSURE WIND TUNNEL TEST PLAN

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ABSTRACT

This report outlines the force and pressure wind tunnel test of general protuberances for the Saturn vehicles to be performed at the Douglas Aerophysics Laboratory 4 foot by 4 foot trisonic wind tunnel.

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1.0 INTRODUCTION

Due to the basic design of the Saturn vehicle, several systems protrude from the external surface of the airframe. The three-dimensional viscous character of the flow environment around these protuberances causes the analytical prediction of the loads to be extremely difficult. The only method available resulting in sufficiently accurate data before flight testing is to simulate these systems in a wind tunnel test.

The preliminary test report, reference (1), included both this test and the heat transfer test. It has been decided that these two tests and their documents be administered separately. Also, included in the preliminary test report was the analysis used to justify simulating the cylindrical vehicle surface by a flat plate and a discussion of the wind tunnel simulation of the actual flight environmental conditions.

This document contains the details of the models and instrumentation to be employed for the general protuberance force and pressure test. Included in this report are descriptions of the wind tunnel facility, the data recording systems, the data reduction procedure, and the test concept and objectives. The planned program schedule and wind tunnel run schedules are also presented. The test is divided into four phases: general pressure test, force test, transverse rings test, and S-IC interference test.

2.0 TEST OBJECTIVES AND CONCEPT

The force and general pressure test models consist of a nose section, a body section, and an afterbody section. Figure 1 shows the general configuration of the models. The bodies are a semi-cylinder on a rectangular parallelepiped and the noses and afterbodies are an oblique semi-cone on a tapered wedge. A discussion of the models to be used in the transverse rings test and the S-IC interference test is found in the following sections.

The plate that the models will be mounted on has stringers which simulate not only the outer surface of the S-IVB stage, but the other stages of the Saturn V vehicle where stringers may exist. It is possible to use a flat plate to simulate the vehicle surface without data degradation, because the diameter of the vehicle is very large compared to the protuberance height and the short radial arc of the vehicle surface simulated.

The plate is the same simulated vehicle surface mounting plate developed for the Auxiliary Propulsion System (APS) test, references (2)&(3), modified as follows: the field splice ring will be removed because it is peculiar to the S-IVB stage. The stringers will be lengthened approximately 15 inches, in order that they will extend several inches upstream of the models to allow stabilization of the flow before reaching the models. A number of static pressure orifices have been added to the plate to obtain the required data. One row of stringers on each side of the plate centerline will be removed in order that the models can be located between stringers instead of above them. Figure 2 shows the revised plate and all of the pressure orifice locations.

The criteria for proper simulation of the model to the vehicle is the relationship between the wind tunnel boundary layer height and the vehicle boundary layer height. Since the wind tunnel boundary layer will be utilized to simulate the boundary layer over the vehicle, the tunnel boundary layer will determine the model scale. Figure 3 is a plot of wind tunnel boundary layer height over the plate as a function of Mach number. Analytical plots of the boundary layer thickness over the Saturn V vehicle, reference (1), show that many of the protuberances on the vehicle are almost equal in height to the vehicle boundary layer. Optimum simulation for our Mach number range is achieved by use of a 2.5 inch caliber for the force and general pressure test models. The models are one caliber in height and one caliber wide.

2.1 General Pressure Test

Three models will be mounted individually on a plate simulating the vehicle outer surface. The static pressure will be measured at several locations on the models and the resulting data will be utilized to determine protuberance skin thickness requirements in addition to providing a correlation with force test wind tunnel data. The models to be employed and their pressure orifice locations are shown in figure 4. Simultaneous with recording the model static pressures, the static pressure will be recorded at various locations on the plate which simulates the vehicle surface. The plate pressures will be recorded for all runs excepting those repeated in the force test. However, static pressure data will be measured under the model on all runs for both the pressure and force tests to verify the effectiveness of the seal used between the bottom of the model and the plate during the force test. During the pressure test the opening between the model nose and the plate will be taped to demonstrate a perfect seal configuration of the seals used in the force test.

The data obtained from the three models tested will demonstrate the effect of changing body length and nose or afterbody angle.

Combinations to be used are: 15 degree nose and afterbody with a 3 caliber body; 15 degree nose and afterbody with a 1 caliber body; 30 degree nose and afterbody with a 3 caliber body.

The plate will be yawed to 5 and 10 degrees to study this effect on selected runs. This is accomplished by unfastening the plate from the tunnel floor and rotating the entire assembly to the desired angle.

Figure 5 shows the plate and the pressure orifice locations which will be used for the general pressure test (and the force test). Also shown in this figure is the ramp (aft of station 22.912) which is used in the force test only.

2.2 Transverse Rings Test

A model simulating the circumferential transverse rings on the surface of the RIFT stage of the Saturn V vehicle will be tested to determine the effect on the pressure distribution of a variation in distance between the rings. The transverse rings are simulated by placing metal strips on the plate perpendicular to the stringers. These rings are the same cross section as the stringers. Figure 6 shows the location of the simulated rings on the plate. Several segments of rings are mounted on the plate with various spacings between the rings. The static pressure will be measured at the locations shown in figure 6 to determine the loads on the vehicle surface. Testing will be performed to determine if extreme pressure regions exist immediately ahead of or behind the rings.

2.3 S-IC Interference Test

The general protuberances used in the tests are representative of protuberances existing on most of the Saturn vehicle stages. One section in particular, however, requires closer attention. The rearmost stringer section of the S-IC stage includes protuberances not adequately duplicated and, therefore, necessitates a separate test.

Wooden models simulating a shroud and several protuberances on the S-IC stage will be mounted on the plate. Figure 7 shows the interference models on the mounting plate with the pressure orifices to be used, and figure 8, the models. Only a quarter section of the shroud will be used in order to have a model cross-sectional area which will not block the tunnel and because the scale used (1/10) makes it possible to use the existing plate with stringers to simulate the S-IC stage.

A knife edged splitter plate will be attached to the shroud to create a mirror image effect at M = 0.8 and M = 1.2. The plate will not be used above M = 1.2 because of shock wave effects. Although a weak shock will be formed at M = 1.2, the splitter plate will still be used to avoid cross-flow effects over the shroud. Analysis of the static pressure distribution measured on the vehicle surface results in the total loads on the skin, and an attempt will be made to use this data to indicate what portion of these loads are interference induced.

2.4 Force Test

Aerodynamic forces and moments on the protuberances will be determined. In addition, pressures will be measured on the surface surrounding the protuberance to evaluate the effect of the fairing on the local flow field. A base pressure probe consisting of two or three static pressure orifices will be attached to the plate for use on runs with no afterbody in the configuration. The ramp, or simulated aft interstage, used in the APS test will be used in the force test on a limited number of runs to simulate the S-IVB-S-II interstage. The ramp and pressure orifice locations are shown in figure 9.

Figure 5 shows the plate with the orifices to be used in the force test and the ramp as it will appear when attached. Wakes and separated regions caused by the protuberance will be of particular interest. Several combinations of noses, bodies, and afterbodies will be tested and the effect of protuberance geometry on the loads and local pressure distribution will be examined.

Noses and afterbodies to be tested include 15 degree and 30 degree shapes. Body lengths of one caliber and three calibers will be tested in conjunction with the different noses and afterbodies. Some configurations will be run without an afterbody and one with a body alone.

Yaw angles to be tested are 0 degrees, 5 degrees, and 10 degrees for selected Mach numbers. A complete survey of the tunnel boundary layer will be made at M = 1.6 and M = 2.0 at the beginning of the force test using the boundary layer rake constructed for the APS test. If good agreement is evidenced, then the boundary layer survey below M = 1.6 from the APS test will apply to this test. A boundary layer trip will be utilized to increase the boundary layer height and several runs will be made to show the effect on the same protuberances of a thicker boundary layer. This new boundary layer will be surveyed at M = 0.8, M = 1.2, and M = 1.6 so that its height will be accurately known.

The force models will be mounted slightly above the plate in order that clearance will be maintained during deflections of the model force balance. A seal will be used between the model nose and the plate to prevent air flow under the model invalidating the data. However, this seal will be designed so that is does not restrict the model force balance deflections. A fouling circuit to warn of contact between the seal and the plate is necessary. The pressure data taken under the models during the force test will be compared with pressure data taken during the pressure test to demonstrate the seal effectiveness.

3.0 PROGRAM SCHEDULE

The planned schedule for the program, based on estimates of the Douglas Aeroballistics Section, the Model Test Group, and the Aerophysics Laboratory is presented in figure 10. This figure indicates the test will be started the first week of February and will have a duration of approximately 10 days. The final reports are expected to be completed by May, 1964.

4.0 RUN SCHEDULE

The enclosed run schedule, table I, indicates the configurations to be tested and their corresponding yaw angles and wind tunnel Mach numbers. This is a summary run schedule and the actual order of the runs and the manner of tunnel operation may differ to obtain the most satisfactory run schedule from a tunnel occupancy time standpoint.

5.0 MODEL INSTRUMENTATION

5.1 Pressure Instrumentation

All static pressure data will be obtained from instrumentation consisting of an orifice flush with the model surface or plate and a piece of tubing which will connect the orifice to a pressure scanner. The pressure scanner gang switches 16 model pressures to 16 transducers in the scanner. Each of the transducers is connected to one of 16 available channels in a Gianinni data recording system. Sixteen model pressures are read each 0.8 seconds and the gang switch rotates to 10 sets of 16 pressures (each set may be from different pressure orifices). Thus, in the pressure mode up to 160 measurements can be recorded each eight seconds. The capacity is reduced by a few channels to record tunnel properties and further reduced by a few additional channels during the force test to record force data. Figure 11 lists the orifices to be used for each test.

As the number of pressure measurements taken increases, the run time of the wind tunnel increases. This depletes the air in the storage tanks and causes additional time to be expended on recharging. Therefore, only the number of orifices required to obtain sufficient data for each test will be utilized.

5.2 Force Instrumentation

The forces and moments acting on the protuberances during the wind tunnel test will be measured with a strain gage balance. Six component force and moment data will be taken. Components to be measured are normal, axial, and side forces, pitching, yawing, and rolling moments. Loading of the balance produces a deformation of the strain gages. This in turn alters the amperage through the gage and unbalances the Wheatstone Bridge circuit. The Wheatstone Bridge circuit is previously calibrated with known loads so that the electrical output represents a given load.

6.0 DATA RECORDING, HANDLING, AND REDUCTION

6.1 Pressure Test Data

The following data will be obtained during the pressure tests:

- Run number
- Mach number
- Yaw angle (degrees)
- Pressure tap location
- Pressure ratio (P_L/P_∞)
- Pressure coefficient $C_p = P_L - P_\infty/q_\infty$
- Stilling chamber total pressure (psf)
- Stilling chamber stagnation temperature ($^\circ$F)
- Test section static presssure (psf)
- Reynolds number (/inch)

The accuracy of the pressure measurements will be 0.05 psi.

6.2 Force Data

Six component force and moment data referenced to the body axis, figure 12, will be measured and will be presented in coefficient form. The location of the moment reference is at the bottom of the model and lies on the x-z plane, figure 13. The reference area, reference length, and moment reference needed for calculation of coefficients are also listed in figure 13.

The accuracy of the force data will be 1 per cent of the maximum expected loads. The expected loads are based on a 2.5 inch caliber, a dynamic pressure of 14 psi, and a maximum yaw angle of 10 degrees, and are listed below.

NORMAL FORCE F_N	AXIAL FORCE F_A	SIDE FORCE F_Y	PITCHING MOMENT M_Y	YAW MOMENT M_Z	ROLL MOMENT M_X
-191 LBS	94 LBS	147 LBS	-727 IN. LBS	292 IN. LBS	147 IN. LBS

DOUGLAS

6.3 Shadowgraphs

Shadowgraphs will be taken over the forward section of the plate during the force test runs without the ramp. Also, shadowgraphs will be taken over the aft portion of the plate during force test runs with the ramp and during the interference test.

7.0 WIND TUNNEL FACILITY

All facilities and equipment needed to conduct this program are currently available within the Douglas Aircraft Company, Missile and Space Systems Division. These include the engineering facilities required for design of the models, a model shop capable of fabricating and instrumenting the models and support equipment, IBM 1620 and 7090 computing facilities required for data reduction and analysis, and the wind tunnel test facility.

The Douglas Aerophysics Laboratory 4 foot by 4 foot tunnel located at El Segundo, California, is a blowdown-to-atmospheric facility. Tabulated below are several of the pertinent operational characteristics.

Mach number	Variable from 0.2 to 5.0
Run time	30 to 60 seconds
Stagnation pressure	20 to 50 psia depending on M
Stagnation temperature	60° to 90°F at M = 4.0 and below 120° to 200°F at M = 4.5 and above
Dynamic pressure	1200 to 3500 psf
Reynolds number	0.5×10^6 to 2×10^6 per inch
Boundary layer thickness	1.5 to 4.5 inches
Pump up time	10 to 20 minutes
Angle of attack range	-15° to 25° with straight sting
Storage pressure	525 psia
Storage volume	26,250 ft^3
Thermal mass	60 tons of galvanized steel tubing

A schematic of the design features of the tunnel is shown in figure 14.

In addition to the tunnel itself, the facility contains or has directly available the following associated equipment:

a. A shadowgraph system capable of producing shadowgraphs at 2 second intervals.

b. A 16 channel digital system capable of recording data every 0.6 seconds on IBM punch cards.

c. A pressure scanner which uses 16 pressure transducers and switches 10 pressures to each transducer enabling up to 160 pressures to be sensed every 8 seconds.

d. A Benson-Lehner electroplotter with a speed of approximately 1,200 points per hour for as run and summary plots.

e. An auxiliary air supply system.

f. A channel direct writing recorder with up to a 100 cps response.

8.0 PROPOSED DATA ANALYSIS

The data obtained from this test should be directly applicable to the full scale vehicle, because the model shapes, the model size relative to the tunnel boundary layer, and the test conditions closely simulate the actual flight environment.

8.1 General Pressure Test

Determination of the pressure distribution over the protuberance surfaces will define the local skin thickness requirements. The pressure field surrounding the protuberances will be investigated to evaluate wakes and separated regions created by their presence as well as their effects on the pressure distribution on the vehicle surfaces.

The effect of protuberance geometry on the flow field in the vicinity of the protuberance will be studied.

8.2 Transverse Rings Test

Pressures measured between the transverse rings will be used to calculate the loads on the surface. In addition, the effect of varying the spacing between rings will be noted.

8.3 S-IC Interference Test

Pressures measured on the simulated S-IC stage in the S-IC interference test will be used to calculate the total loads on the surface.

8.4 Force Test

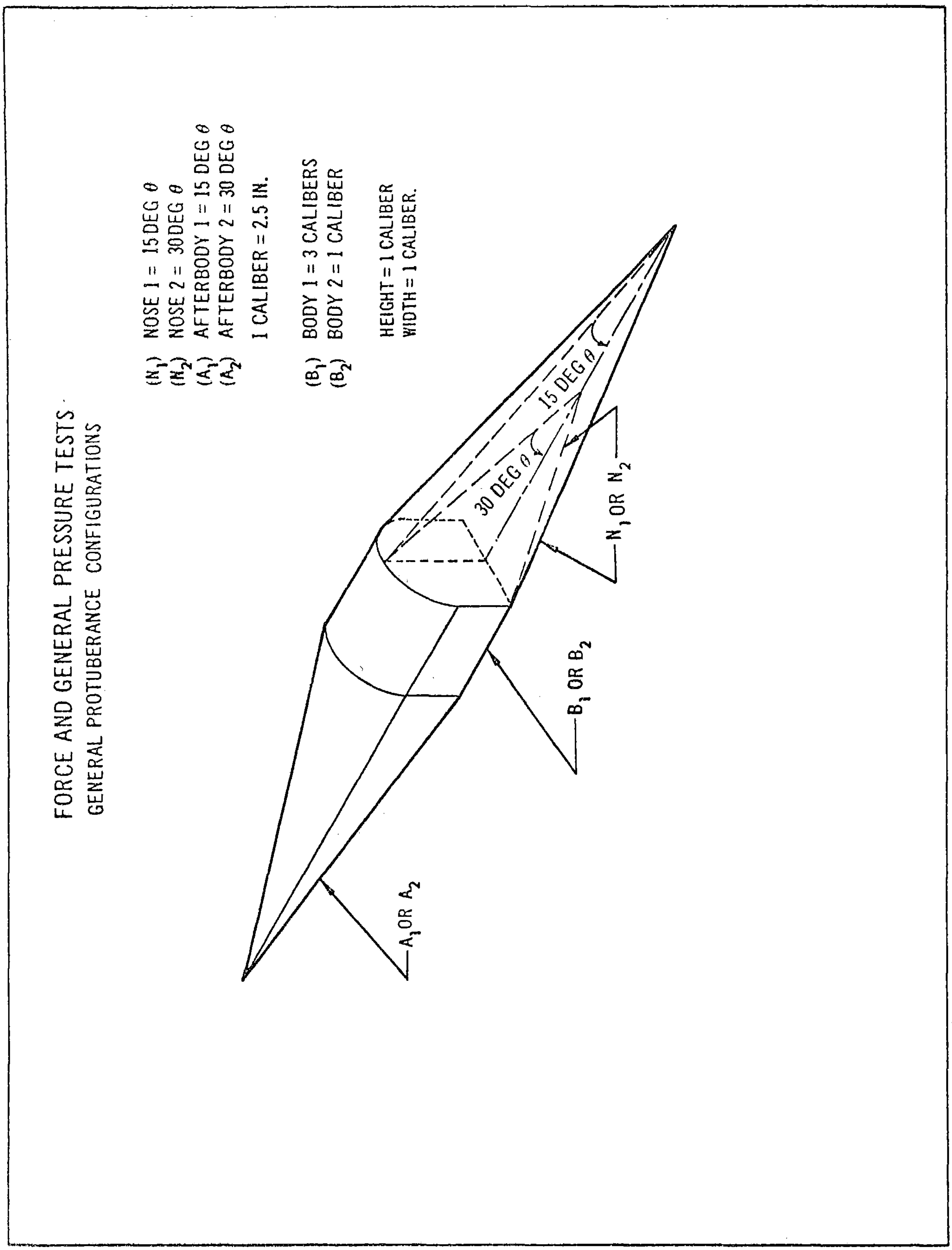
Data from the force test will provide loads and moments on the protuberances, which will be a function of protuberance geometry.

The effect on the loads of varying the boundary layer height and the protuberance induced loads on the vehicle surface will be investigated.

9.0 TEST PERSONNEL

The Saturn Aeroballistics section is responsible for experimental coordination which includes test planning, supervision of test operations, and technical coordination between DAC and MSFC, NAA, Boeing, and Lockheed. The Aeroballistics section will also perform all of the data analysis and will be responsible for all of the final reports. The personnel responsible include V. J. Smith, J. E. Vondette, and G. D. Roeck.

D. T. Lloyd of the Model Test group is responsible for coordination of model design and fabrication, and all liaison between the technical sections and the wind tunnel facility.



FORCE AND GENERAL PRESSURE TESTS
GENERAL PROTUBERANCE CONFIGURATIONS
(N_1) NOSE 1 = 15 DEG θ
(N_2) NOSE 2 = 30 DEG θ
(A_1) AFTERBODY 1 = 15 DEG θ
(A_2) AFTERBODY 2 = 30 DEG θ
1 CALIBER = 2.5 IN.
(B_1) BODY 1 = 3 CALIBERS
(B_2) BODY 2 = 1 CALIBER
HEIGHT = 1 CALIBER
WIDTH = 1 CALIBER.
15 DEG θ
30 DEG θ
N_1 OR N_2
B_1 OR B_2
A_1 OR A_2

FIGURE 1

MOUNTING PLATE AND
PRESSURE ORIFICES

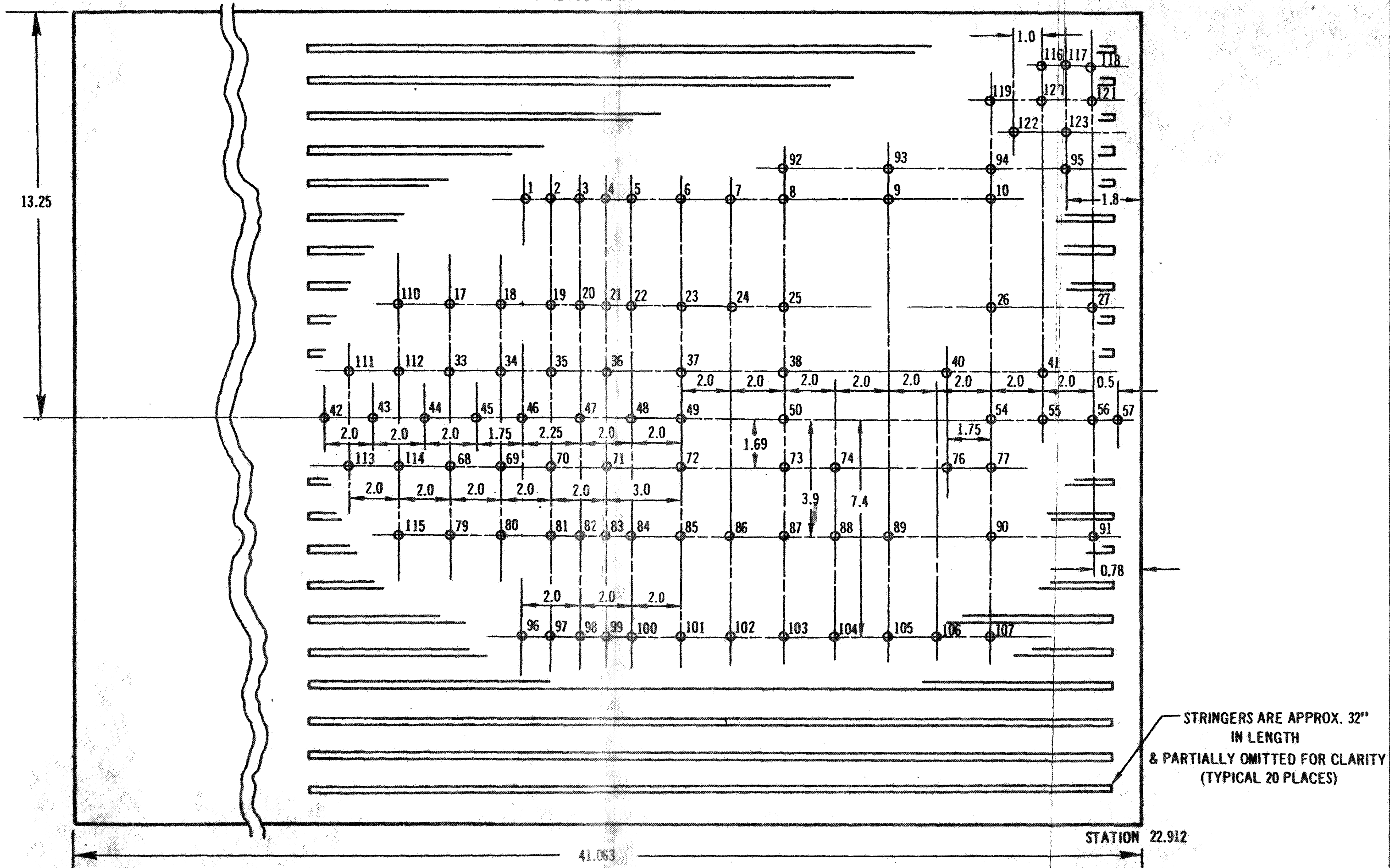


FIGURE 2

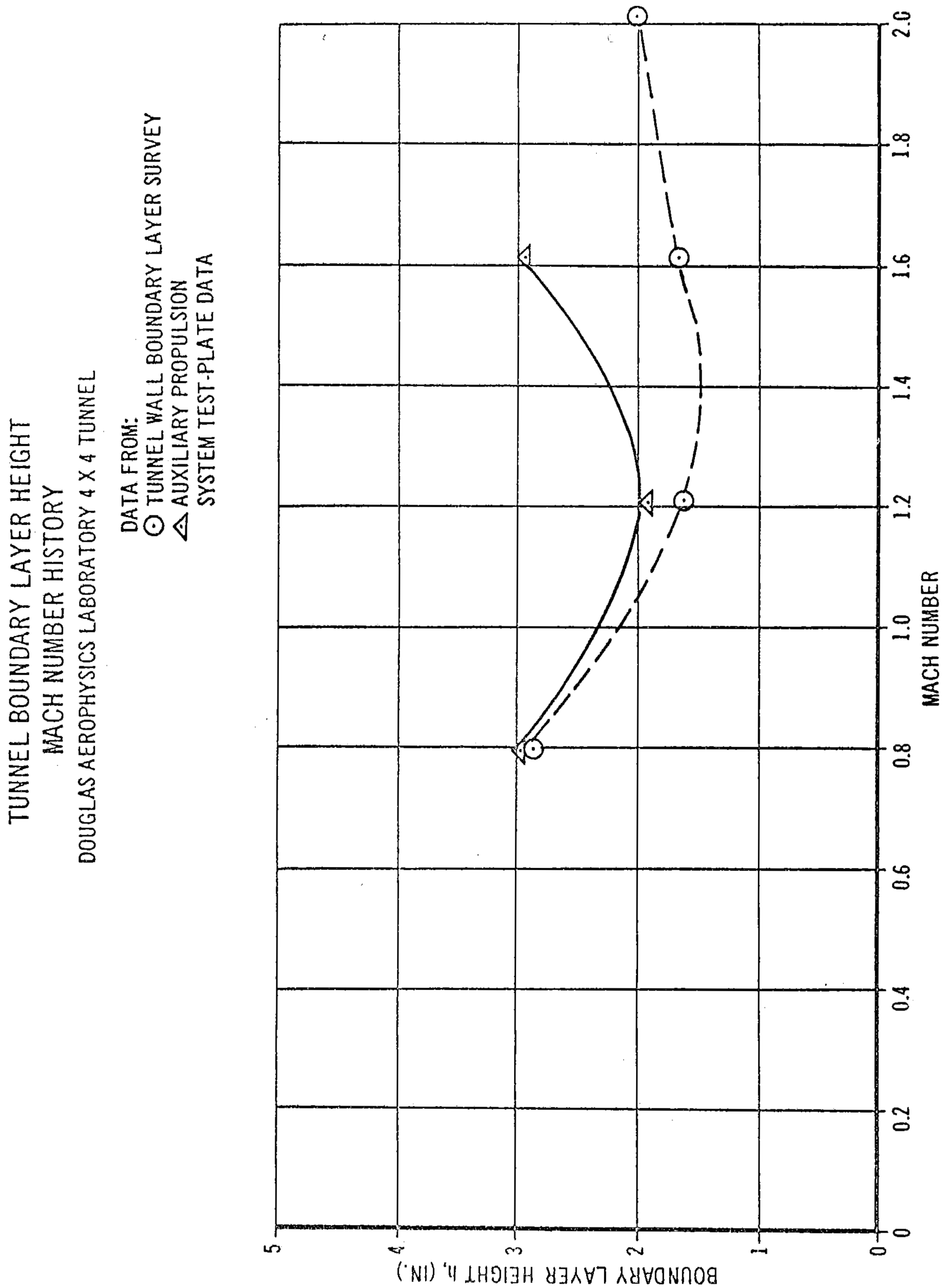
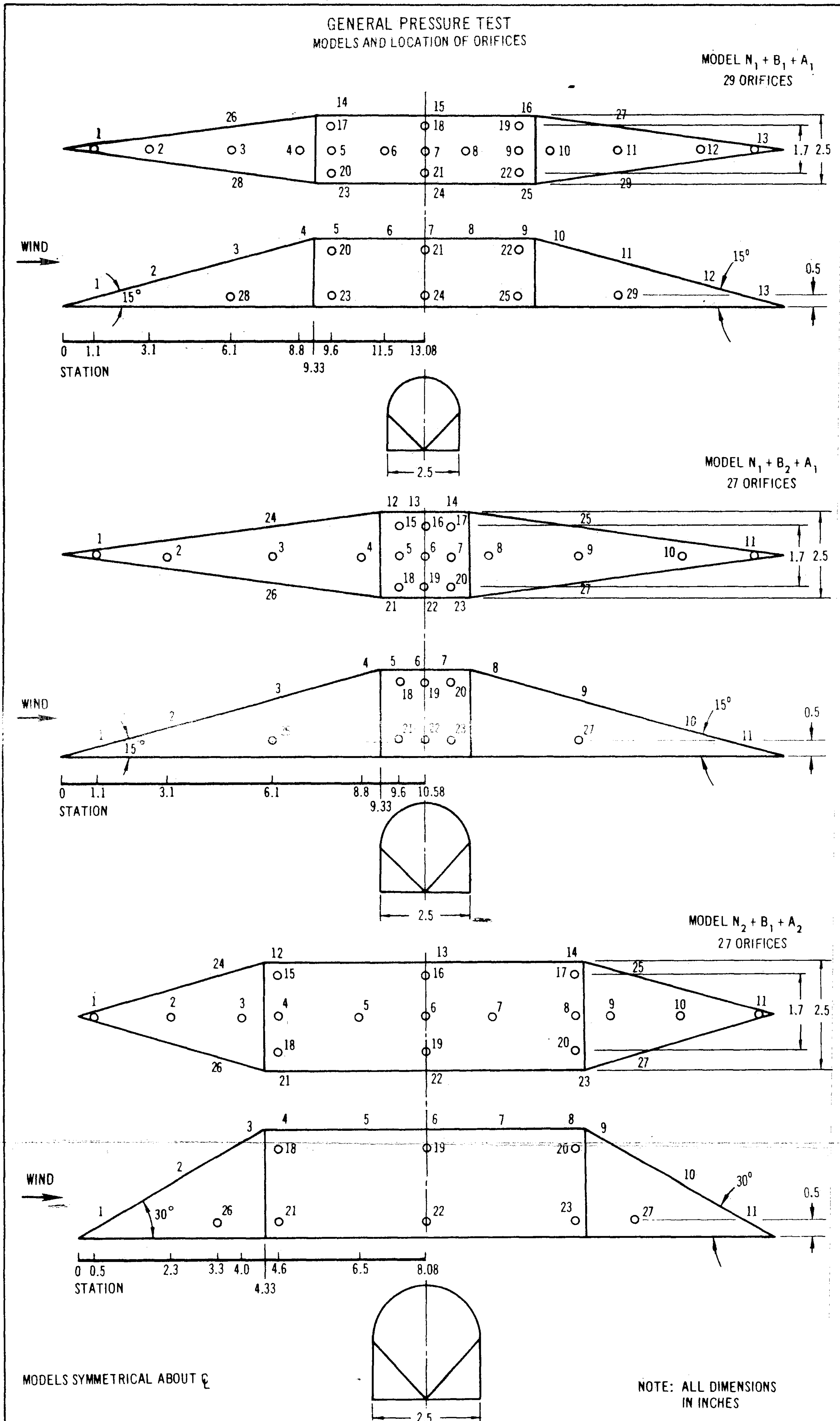

TUNNEL BOUNDARY LAYER HEIGHT
MACH NUMBER HISTORY
DOUGLAS AEROPHYSICS LABORATORY 4 X 4 TUNNEL
DATA FROM:
TUNNEL WALL BOUNDARY LAYER SURVEY
AUXILIARY PROPULSION SYSTEM TEST-PLATE DATA
BOUNDARY LAYER HEIGHT h, (IN.)
MACH NUMBER
0
1
2
3
4
5
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

FIGURE 3



GENERAL PRESSURE TEST
MODELS AND LOCATION OF ORIFICES
MODEL $N_1 + B_1 + A_1$
29 ORIFICES
MODEL $N_1 + B_2 + A_1$
27 ORIFICES
MODEL $N_2 + B_1 + A_2$
27 ORIFICES
WIND
STATION
MODELS SYMMETRICAL ABOUT ℄
NOTE: ALL DIMENSIONS IN INCHES

FIGURE 4

FORCE AND GENERAL PRESSURE TEST
MOUNTING PLATE, RAMP, AND
PRESSURE ORIFICE LOCATIONS

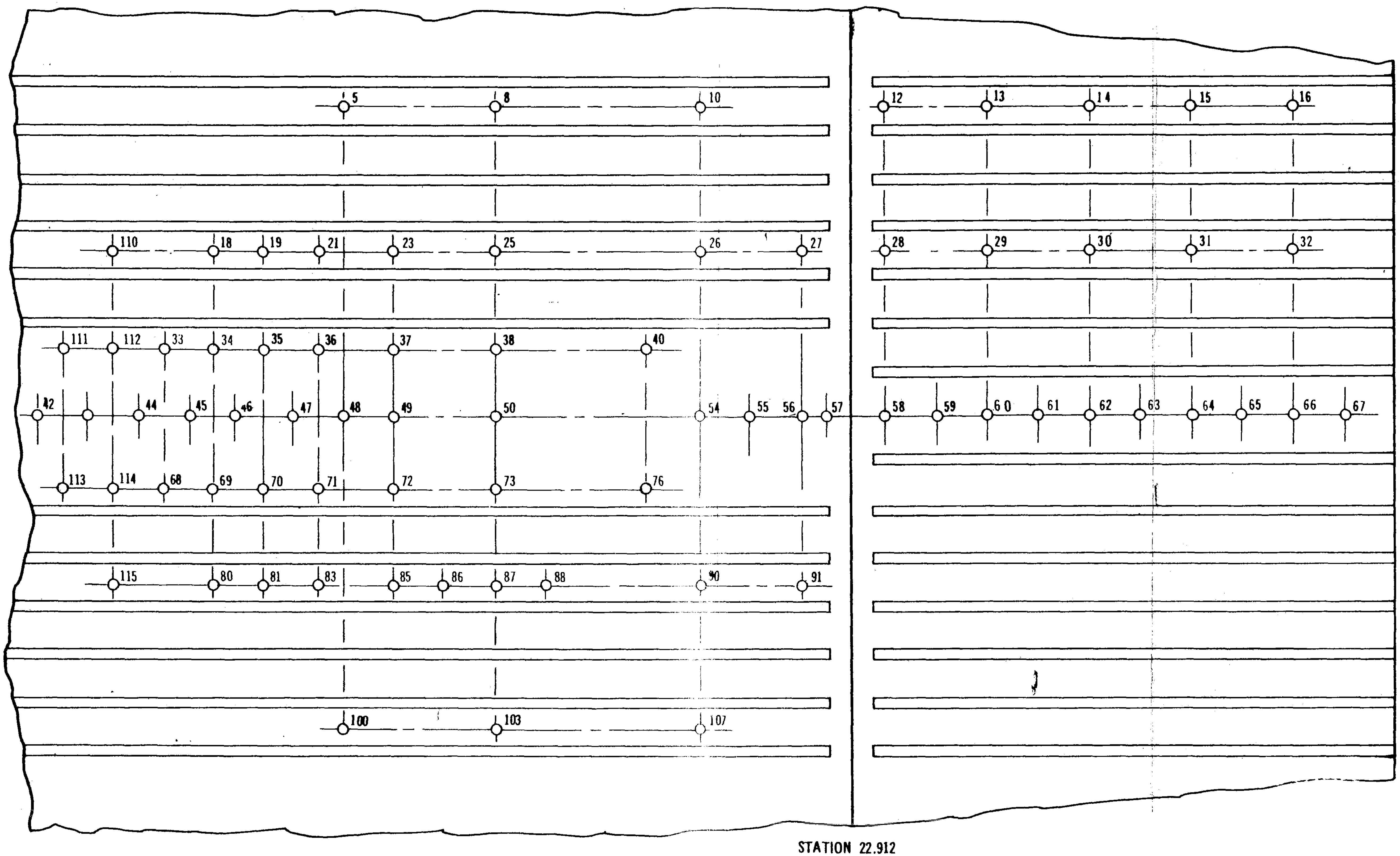


FIGURE 5

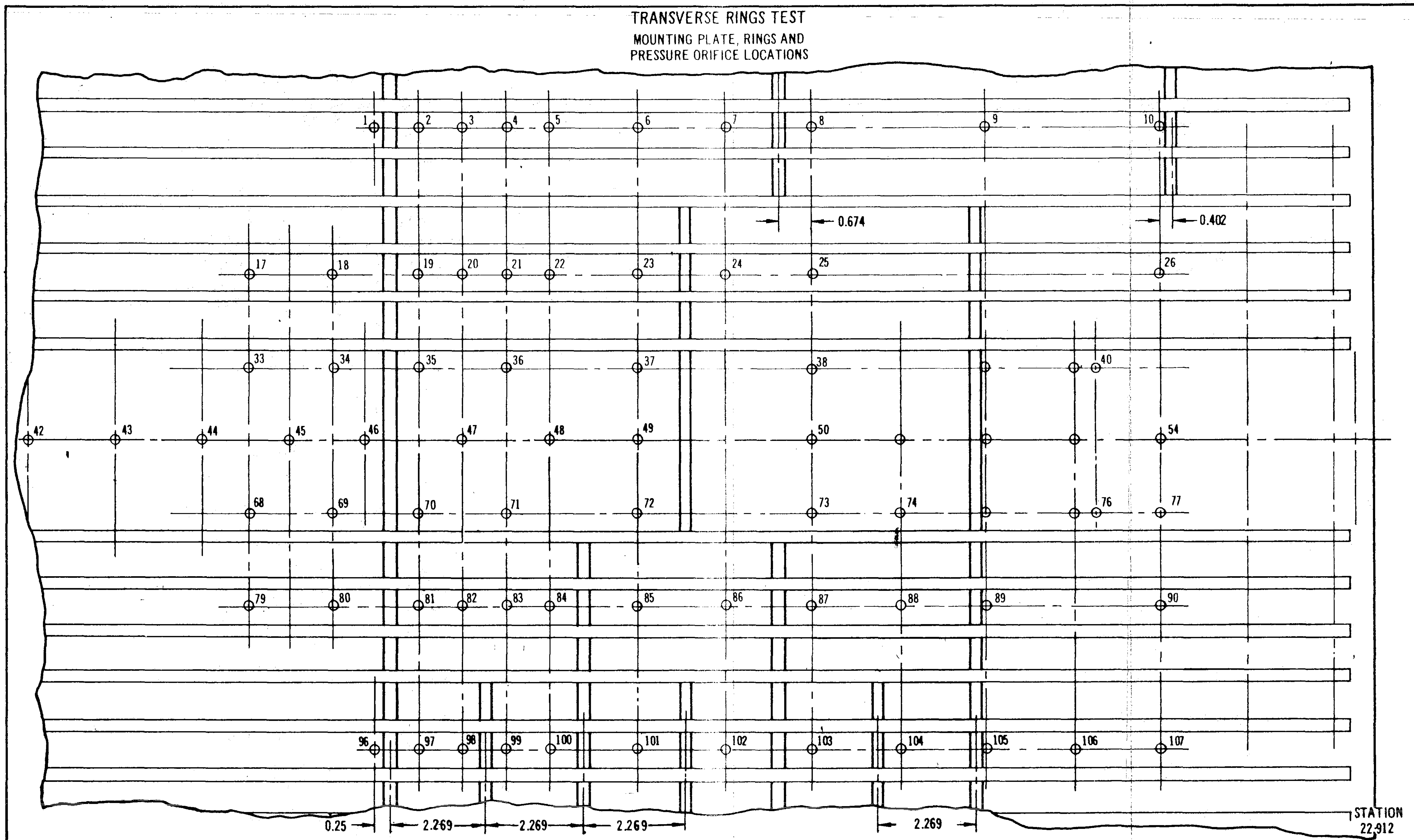

TRANSVERSE RINGS TEST
MOUNTING PLATE, RINGS AND
PRESSURE ORIFICE LOCATIONS
0.674
0.402
0.25
2.269
STATION
22.912

FIGURE 6

S-IC INTERFERENCE TEST
MOUNTING PLATE, MODELS AND PRESSURE ORIFICE LOCATIONS

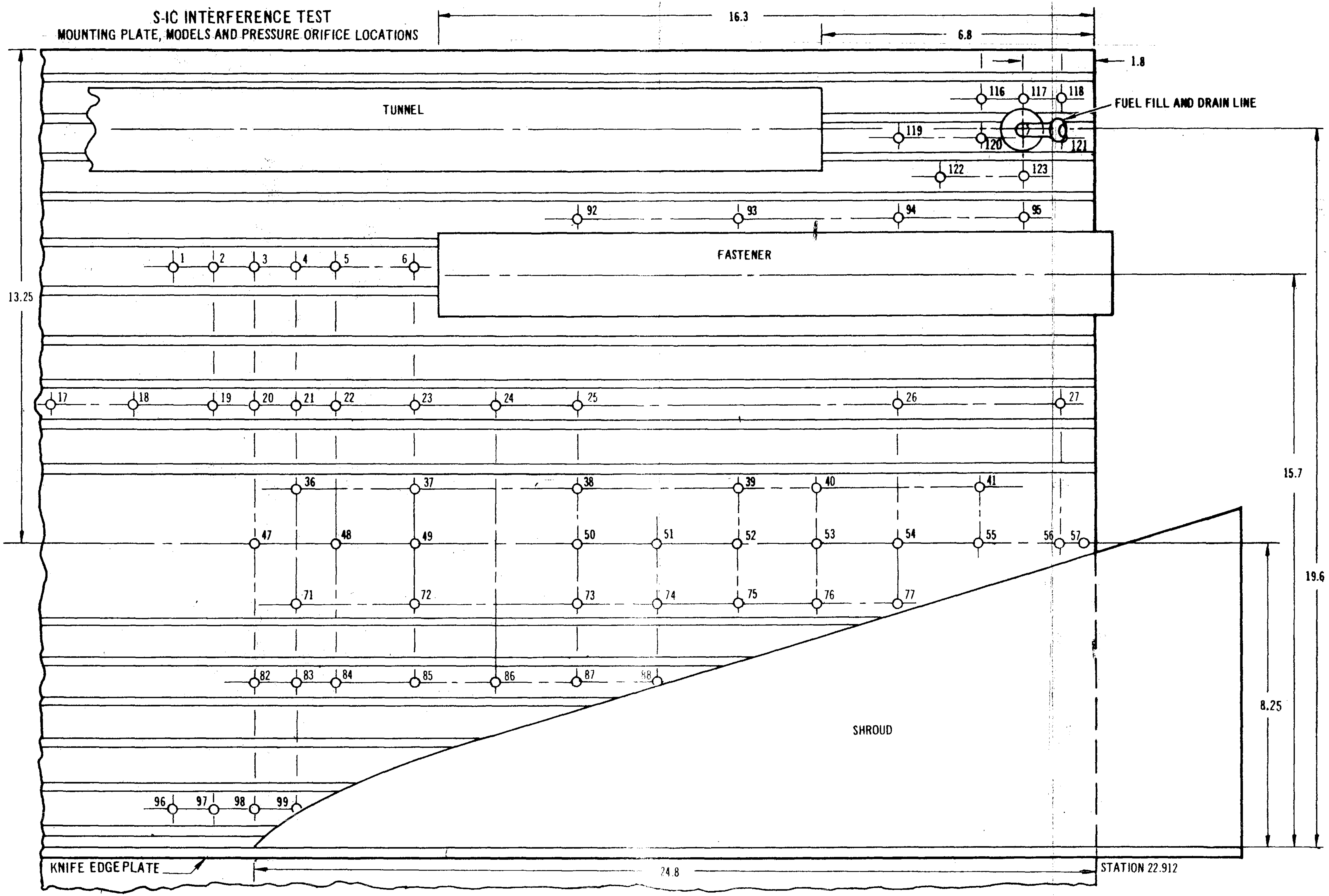


FIGURE 7

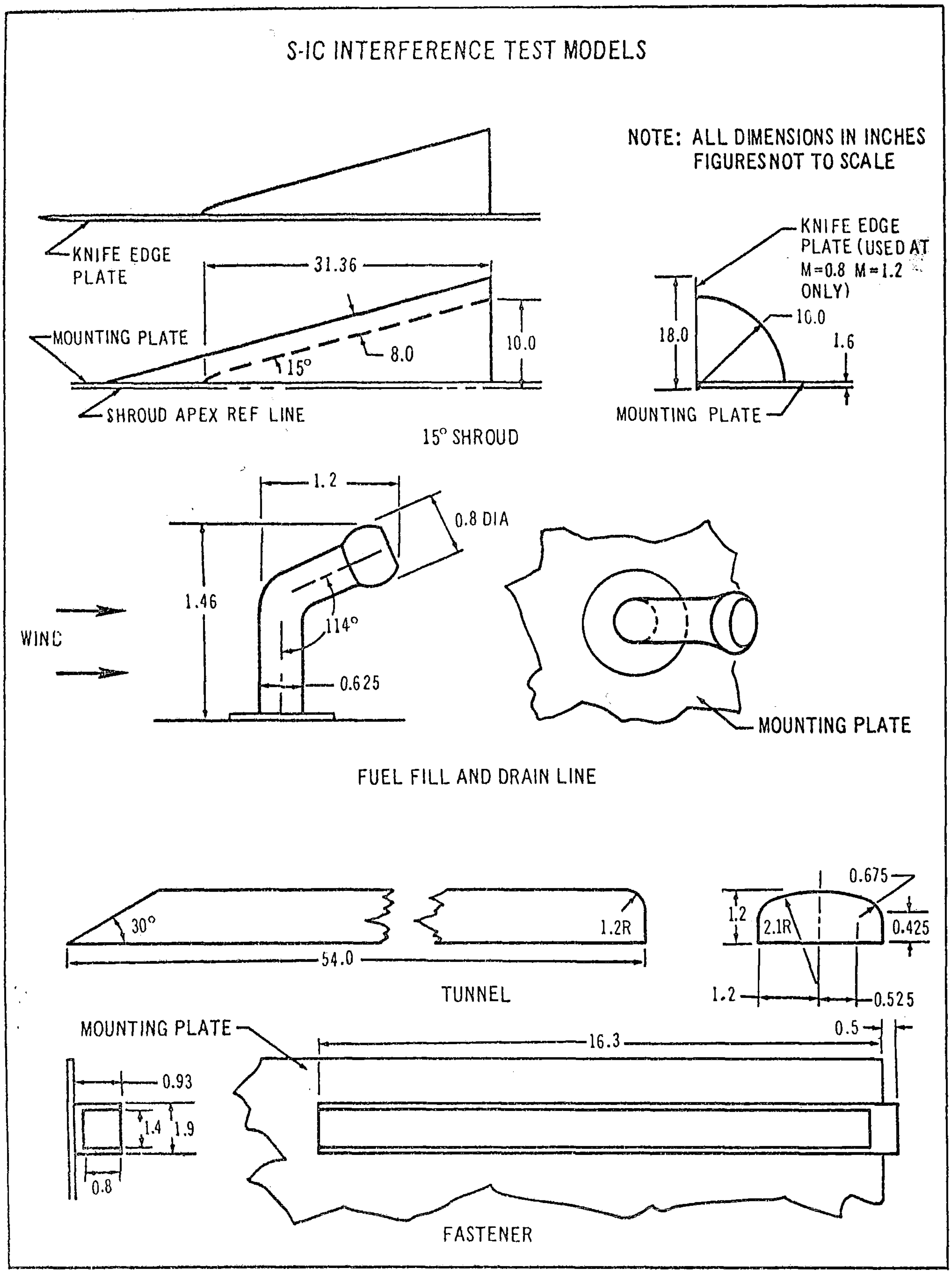
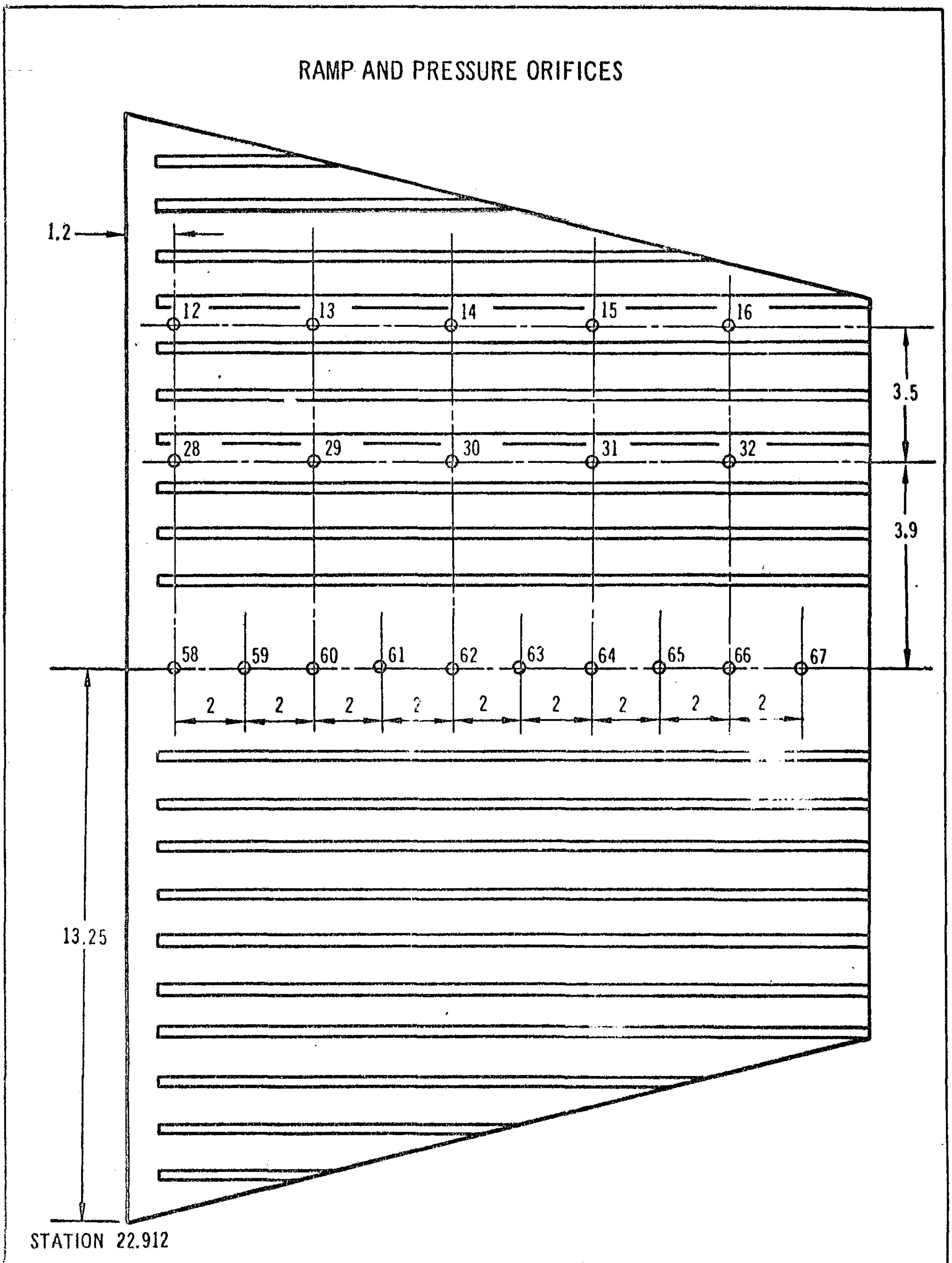

S-IC INTERFERENCE TEST MODELS
NOTE: ALL DIMENSIONS IN INCHES
FIGURES NOT TO SCALE
KNIFE EDGE PLATE
31.36
MOUNTING PLATE
8.0
15°
10.0
SHROUD APEX REF LINE
15° SHROUD
KNIFE EDGE PLATE (USED AT M=0.8 M=1.2 ONLY)
10.0
18.0
1.6
MOUNTING PLATE
1.2
0.8 DIA
1.46
WIND
114°
0.625
MOUNTING PLATE
FUEL FILL AND DRAIN LINE
30°
1.2R
54.0
TUNNEL
0.675
1.2
2.1R
0.425
1.2
0.525
MOUNTING PLATE
16.3
0.5
0.93
1.4
1.9
0.8
FASTENER

FIGURE 8



RAMP AND PRESSURE ORIFICES
1.2
12
13
14
15
16
3.5
28
29
30
31
32
3.9
58
59
60
61
62
63
64
65
66
67
2
2
2
2
2
2
2
2
2
13.25
STATION 22.912

FIGURE 9

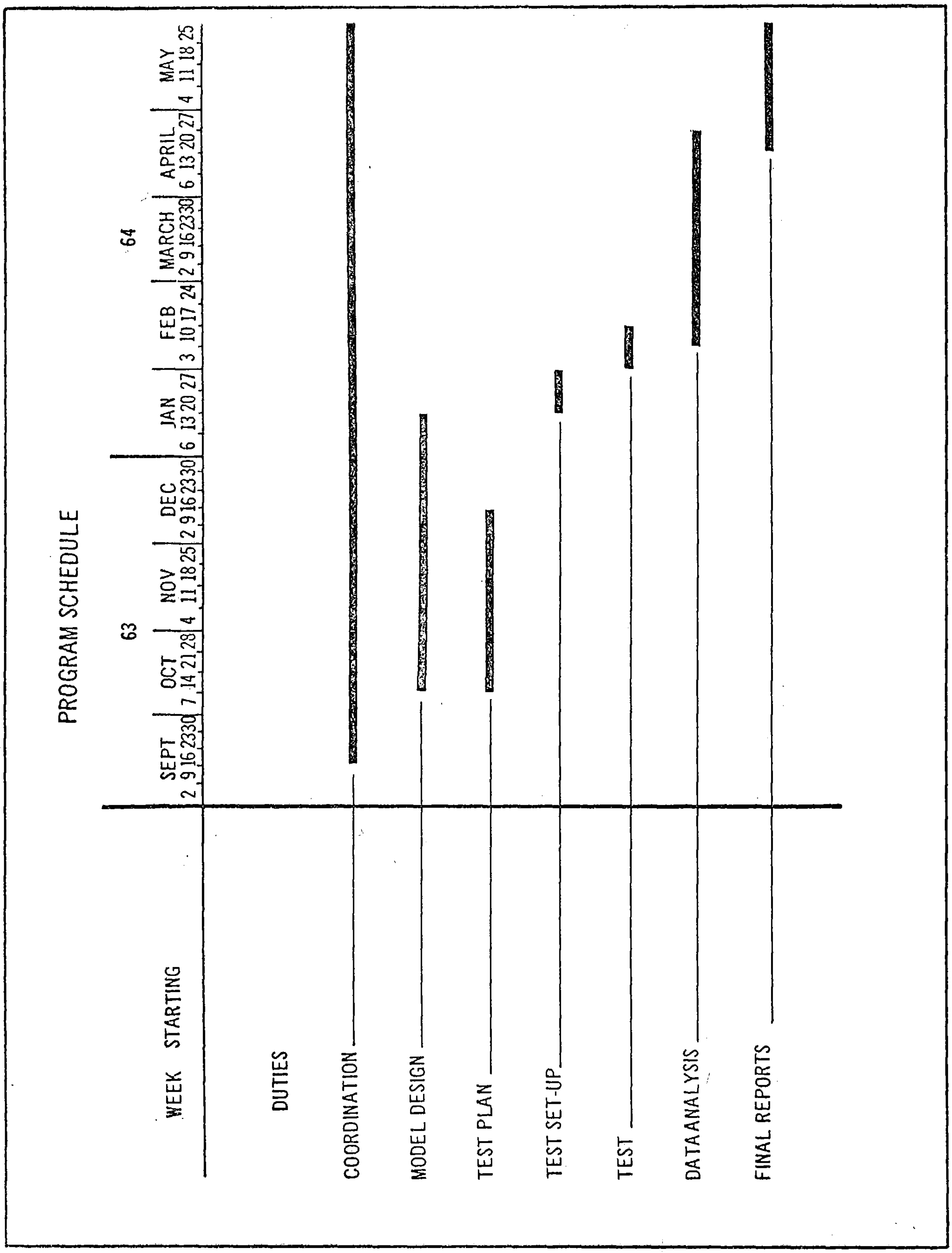

PROGRAM SCHEDULE
63
64
WEEK STARTING
SEPT 2 9 16 23 30
OCT 7 14 21 28
NOV 4 11 18 25
DEC 2 9 16 23 30
JAN 6 13 20 27
FEB 3 10 17 24
MARCH 2 9 16 23 30
APRIL 6 13 20 27
MAY 4 11 18 25
DUTIES
COORDINATION
MODEL DESIGN
TEST PLAN
TEST SET-UP
TEST
DATA ANALYSIS
FINAL REPORTS

FIGURE 10

MOUNTING PLATE AND RAMP PRESSURE MEASUREMENTS

TEST	RUNS	ORIFICE NUMBERS
GENERAL PRESSURE	1, 3, 12, 14	#8, 10, 110, 18, 19, 21, 23, 25-27, 111, 112 33-40, 42-50, 54-57, 113, 114, 68-73 76, 115, 80, 81, 83, 85, 87, 90, 91, 103, 107
	2, 4-11, 13	#42-57
TRANSVERSE RINGS	ALL RUNS	#1-10, 17-26, 33-40, 42-54, 68-77 79-90, 96-107
S-IC INTERFERENCE	ALL RUNS	#1-6, 17-27, 36-41, 47-57, 71-78 82-91, 92-100, 116-123
FORCE	1-39	#5, 8, 10, 110, 18, 19, 21, 23, 25-27, 111 112, 33-40, 42-50, 54-57, 113, 114 68-73, 76, 115, 80, 81, 83, 85-88 90, 91, 100, 103, 107
	40-45	SAME AS RUNS 1-39 PLUS #12-16, 28-32, 58-67
	3-10, 16, 17	SAME AS RUNS 1-39 PLUS BASE PRESSURE PROBE

FIGURE 11

BODY AXIS, FORCE, AND MOMENT
COORDINATE SYSTEM

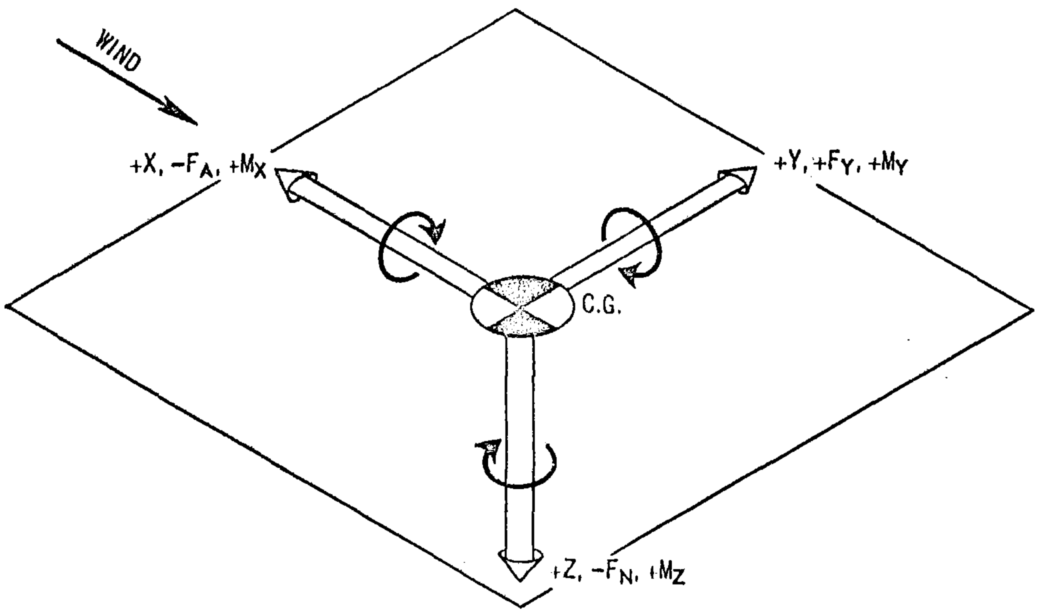
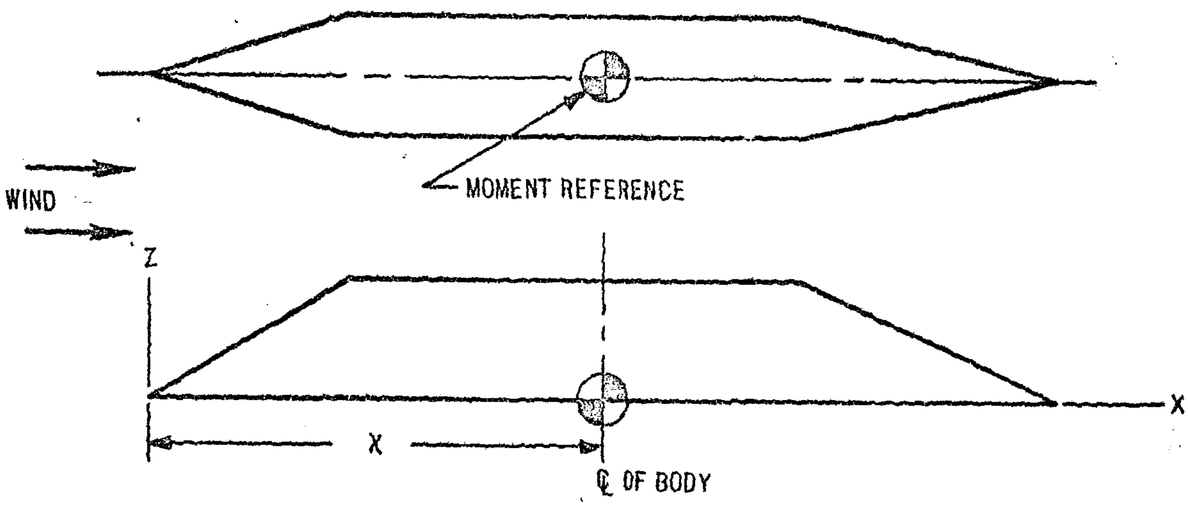


FIGURE 12

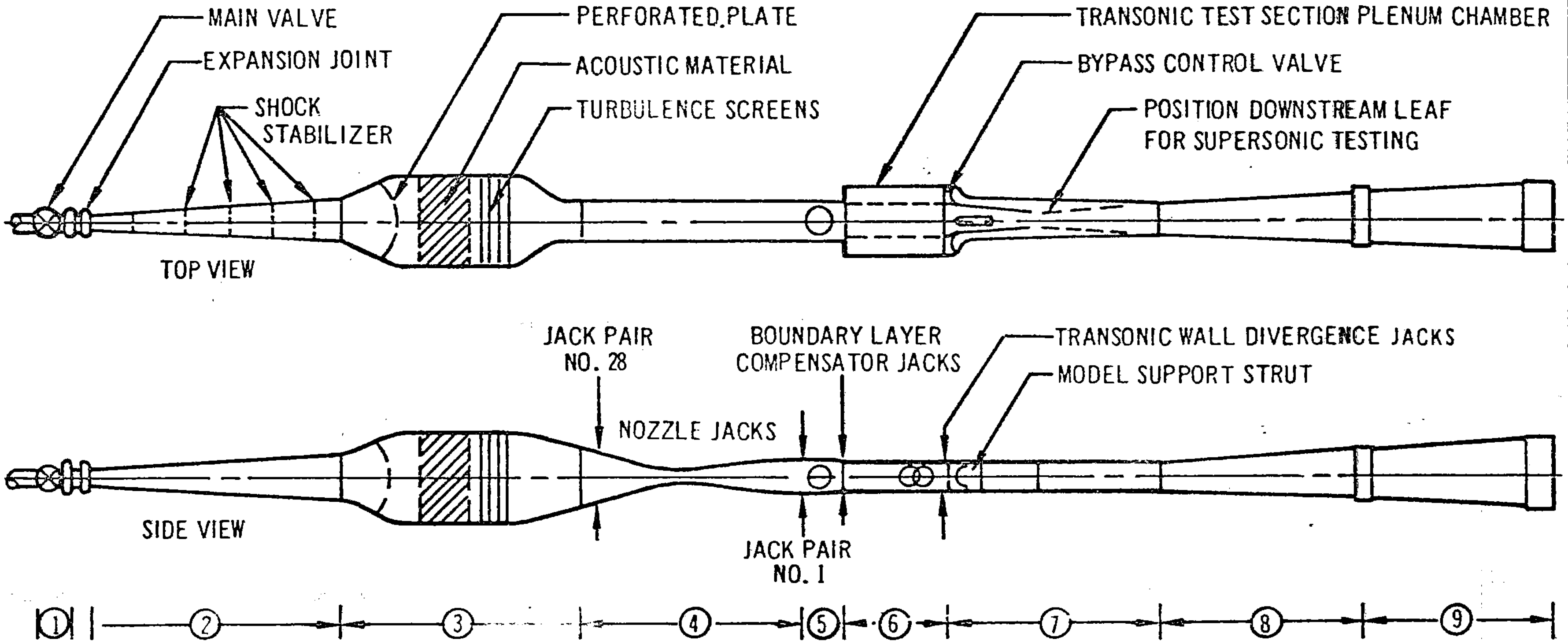
LOCATION OF MOMENT REFERENCE REFERENCE LENGTH AND AREA



CONFIGURATION	MOMENT REFERENCE (X)	REFERENCE AREA	REFERENCE LENGTH
$N_1 + B_1$	13.08 IN.	5.58 $IN.^2$	16.83 IN.
$N_2 + B_1$	8.08 IN.	5.58 $IN.^2$	11.83 IN.
$N_2 + B_1 + A_2$	8.08 IN.	5.58 $IN.^2$	16.16 IN.
$N_1 + B_1 + A_1$	13.08 IN.	5.58 $IN.^2$	26.16 IN.
B_1	3.75 IN.	5.58 $IN.^2$	7.50 IN.
$N_1 + B_2 + A_1$	10.58 IN.	5.58 $IN.^2$	21.16 IN.
$N_2 + B_2 + A_2$	5.58 IN.	5.58 $IN.^2$	11.16 IN.
$N_1 + B_1 + A_2$	13.08 IN.	5.58 $IN.^2$	21.16 IN.

FIGURE 13

DAL TRISONIC FOUR - FOOT TUNNEL DESIGN FEATURES



(1) CONTROL VALVE Valve regulated during run by el[illegible]tro-mechanical controller maintain constant pressur[illegible] chamber.

(2) ENTRY DIFFUSER Entrance cone, 6° includ[illegible] angle; 4 shock stablizier rings.

(3) STILL CHAMBER Dished, 30% open-perforated plate; acoustic panels for 15-20 db acoustic energy attenuation; 4 turbulence screens.

(4) NOZZLE 2-0.76" thick flexible plates, each controlled by 28 jacks; contours for Mach 1.0 to 5.0.

(5) SUPERSONIC TEST SECTION 60" long 30" dia. windows in sidewalls; 24" openings top and bottom; boundary layer compensation by adjustable divergence on top and bottom walls, +0.13° To -0.50.

(6) TRANSONIC TEST SECTION 144" long; 30" dia. windows at one of two positions; 4 walls perforated 22% open, holes normal to wall. Adjustable divergence on top and bottom walls, +0.25° to -2°. Section removable and downstream circuit moves up.

(7) MODEL SUPPORT, BYPASS CONTROL VALVE & VARIABLE DIFFUSER Full hieght vertical struts with vertical motion and -15° to +25° pitch capability, 8" maximum strut width. Bypass valve controls Mach number. Downstream leaf of variable diffuser disconnected from upstream leaf for transonic testing. Variable throat allows extended run times at supersonic Mach numbers.

(8) TELESCOPING DIFFUSER Telescopes into fixed diffuser, retracting model support-variable diffuser, opening tunnel for model installation and changes.

(9) FIXED DIFFUSER Complete expansion to muffler tower.

FIGURE 14

RUN SCHEDULE

GENERAL PRESSURE TEST

RUN	CONFIGURATION	MACH NO.	ψ
1	$N_1 + B_1 + A_1$	2.0	0°
2	$N_1 + B_1 + A_1$	1.6	0°
3	$N_1 + B_1 + A_1$	1.2	0°
4	$N_1 + B_1 + A_1$	0.8	0°
		CHANGE TO $\psi = 5°$	
5	$N_1 + B_1 + A_1$	0.8	5°
6	$N_1 + B_1 + A_1$	1.6	5°
		CHANGE TO $\psi = 10°$	
7	$N_1 + B_1 + A_1$	1.6	10°
8	$N_1 + B_1 + A_1$	0.8	10°
		CHANGE TO $\psi = 0°$	
9	$N_1 + B_2 + A_1$	0.8	0°
10	$N_1 + B_2 + A_1$	1.2	0°
11	$N_2 + B_1 + A_2$	0.8	0°
12	$N_2 + B_1 + A_2$	1.2	0°
13	$N_2 + B_1 + A_2$	1.6	0°
14	$N_2 + B_1 + A_2$	2.0	0°

TRANSVERSE RINGS TEST

RUN	CONFIGURATION	MACH NO.
1	RINGS ON MOUNTING	0.8
2	PLATE	1.2
3		1.6
4		2.0

S-IC INTERFERENCE TEST

RUN	CONFIGURATION	MACH NO.
1	INTERFERENCE MODELS	0.8
2	ON MOUNTING PLATE	1.2
3		1.6
4		2.0

TABLE I

FORCE TEST

RUN	CONFIGURATION	MACH NO.	ψ
1	BOUNDARY LAYER RAKE	1.6	0°
2	BOUNDARY LAYER RAKE	2.0	0°
3	$N_1 + B_1$	1.6	0°
4	$N_1 + B_1$	2.0	0°
5	$N_1 + B_1$	1.2	0°
6	$N_1 + B_1$	0.8	0°
7	$N_1 + B_1$	0.6	0°
8	$N_2 + B_1$	0.8	0°
9	$N_2 + B_1$	1.2	0°
10	$N_2 + B_1$	1.6	0°
11	$N_2 + B_1 + A_2$	1.6	0°
12	$N_1 + B_1 + A_1$	1.6	0°
13	$N_1 + B_1 + A_1$	0.8	0°
14	$N_1 + B_1 + A_1$	0.6	0°
15	$N_2 + B_1 + A_2$	0.8	0°
16	B_1	1.6	0°
17	B_1	0.8	0°
18	$N_1 + B_2 + A_1$	0.8	0°
19	$N_1 + B_2 + A_1$	1.2	0°
20	$N_1 + B_2 + A_1$	1.6	0°
21	$N_2 + B_2 + A_2$	1.6	0°
22	$N_1 + B_1 + A_2$	0.6	0°
23	$N_1 + B_1 + A_2$	0.8	0°
24	$N_1 + B_1 + A_2$	1.6	0°
		CHANGE TO $\psi = 10°$	
25	$N_1 + B_2 + A_1$	1.6	10°
26	$N_1 + B_2 + A_1$	1.2	10°
27	$N_1 + B_2 + A_1$	0.8	10°
28	$N_1 + B_1 + A_1$	0.8	10°
29	$N_1 + B_1 + A_1$	1.2	10°
30	$N_1 + B_1 + A_1$	1.6	10°
		CHANGE TO $\psi = 5°$	
31	$N_1 + B_1 + A_1$	1.6	5°
32	$N_1 + B_1 + A_1$	1.2	5°
33	$N_1 + B_1 + A_1$	0.8	5°
VARY BOUNDARY LAYER BY US[illegible] TUNNEL TO INCREASE HEIGHT			
		CHANGE TO $\psi = 0°$	
34	BOUNDARY LAYER RAKE	0.8	
35	BOUNDARY LAYER RAKE	1.2	
36	BOUNDARY LAYER RAKE	1.6	
37	$N_1 + B_1 + A_1$	1.6	
38	$N_1 + B_1 + A_1$	1.2	0°
39	$N_1 + B_1 + A_1$	0.8	0°
ATTACH RAMP	(NORMAL BOUNDARY LAYER)		
40	$N_1 + B_1 + A_1$	0.8	0°
41	$N_1 + B_1 + A_1$	1.2	0°
42	$N_1 + B_1 + A_1$	1.6	0°
43	$N_1 + B_1 + A_2$	1.6	0°
44	$N_1 + B_1 + A_2$	1.2	0°
45	$N_1 + B_1 + A_2$	0.8	0°

TABLE I CONT

REFERENCES

1. Wilson, S. C., Saturn S-IVB General Protuberance Wind Tunnel Test Preliminary Report, DAC Report SM-43625, dated April, 1963.

2. Melton, H. R., Saturn V/S-IVB Auxiliary Propulsion System Fairing Wind Tunnel Test, DAC Report SM-43624, dated April, 1963.

3. Chalfant, J. J. and J. P. Palmer, Auxiliary Propulsion System Fairing Wind Tunnel Test for the Saturn V/S-IVB Stage, DAC Report SM-44877, dated November 12, 1963.